Progression of Ecological Degradation in Mid-Atlantic Streams

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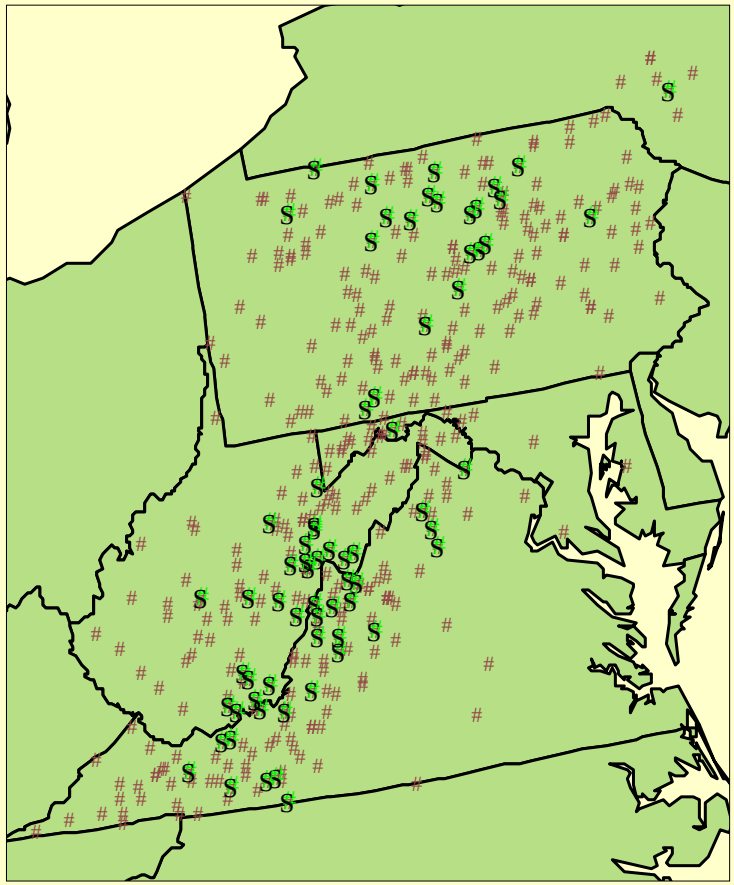
Motivation

- Develop a better understanding of how stream community composition changes as different types of anthropogenic stress increase.
- Develop a method to compare relative severity of ecological effects across different stressors.
- Provide analytical tools to help define aquatic life use tiers.

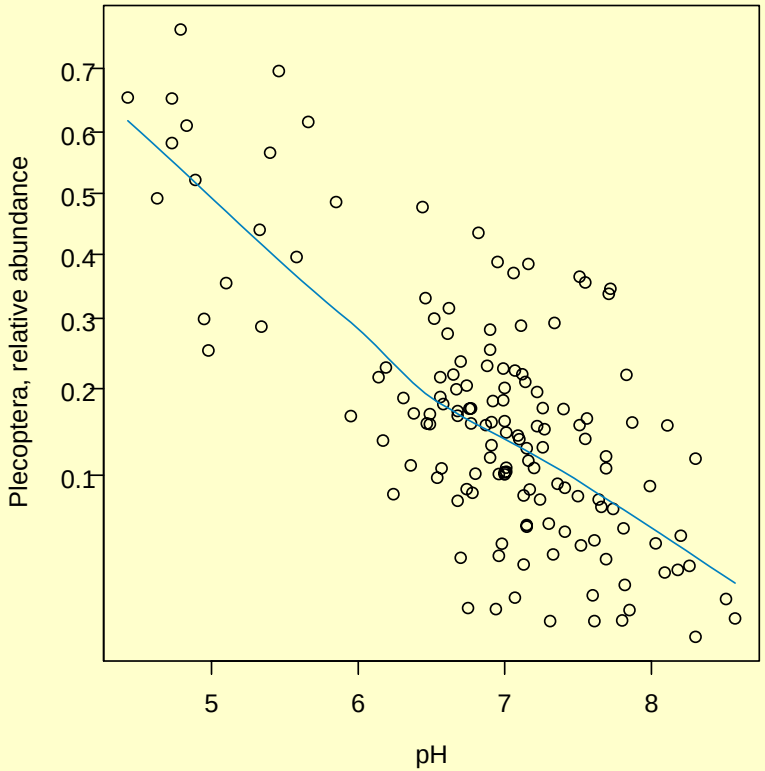
Data

- Data collected by U.S. EPA EMAP Surface Waters Program.
- Streams sampled during summer low flow conditions from 1993-1996.
- Stratified random sampling of mostly 1st - 3rd order streams.
- Collected benthic macroinvertebrates, fish, physical habitat and water chemistry data.
- 491 samples.

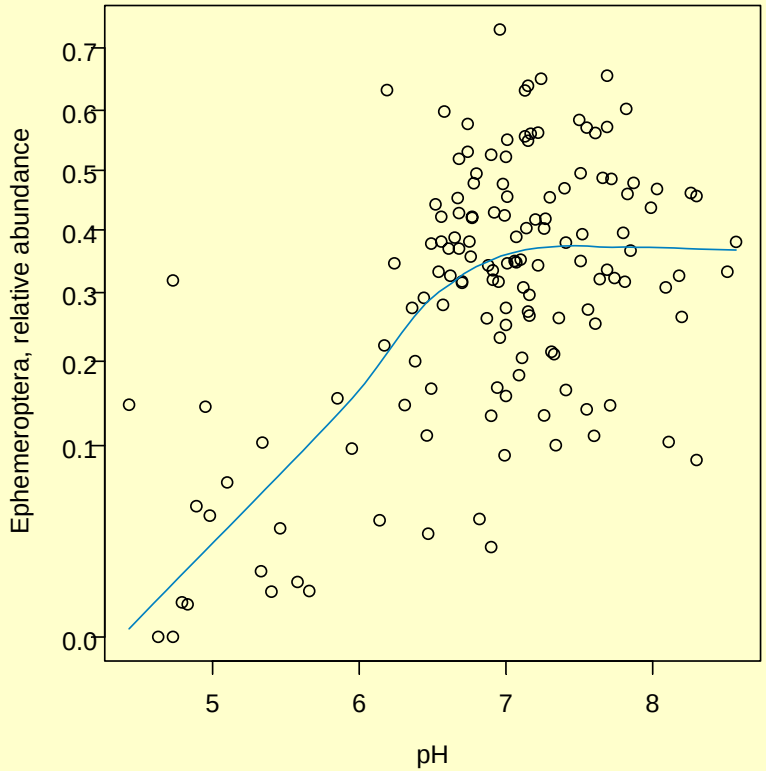


Stressor-Response Curves

PLECOPTERA



EPHEMEROPTERA



How do we rescale the responses so that we can compare them on the same set of axes?

Approach

Scale metrics by the means and variances expected under unimpaired conditions.

Analysis steps:

1. Characterize natural variability in reference sites (stepwise linear regression).
2. Scale biological metrics by reference statistics.
3. Model stressor-response relationships with Generalized Additive Models.

Variables Considered

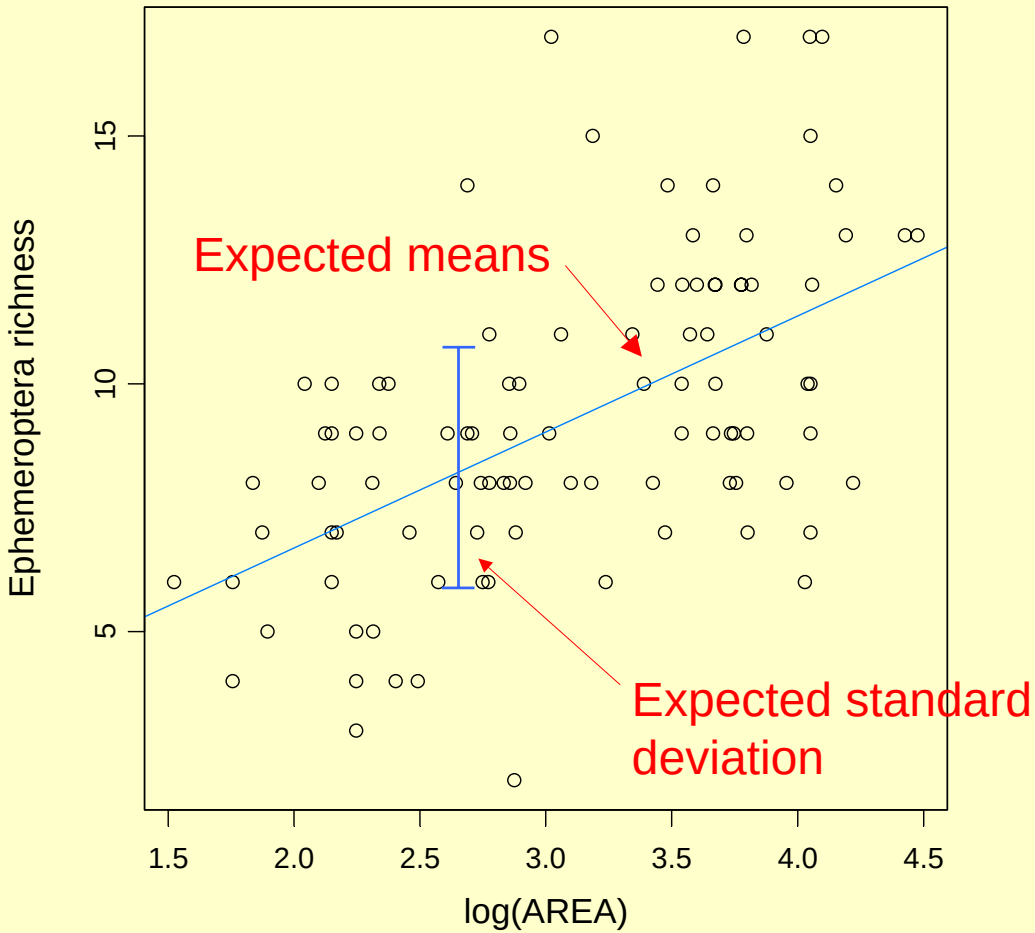
- Biological Metrics
  - Ephemeroptera richness (EPHERICH)
  - Plecoptera richness (PLECRICH)
  - Tolerant richness (TOLRRICH)
  - Tolerant relative abundance (TOLRPIND)
  - Relative abundance of top three taxa (DOM3PIND)
  - Total richness (TOTLRICH)
- Stressors
  - Physical Habitat (RBP)
  - Nutrients (total P)
  - Metals (total dissolved Al)
  - Ion concentration (conductivity)
- Natural Variability
  - Catchment area
  - Elevation

Reference Site Criteria

- ANC > 50 µeq/L
- Total Phosphorus < 20 µg/L
- Total Nitrogen < 750 µg/L
- Chloride < 100 µeq/L
- Sulfate < 400 µeq/L
- Total RBP Habitat Score ❍ 180
- Total number of individuals collected > 150

Control for Natural Variability

Regression relationships are used to compute expected means and standard deviations at reference sites for each metric.



Reference Site Statistics

	Mean	S.D.	R2
EPHERICH	5 - 13	2.5	0.43
PLECRICH	3 - 7	1.9	0.26
TOLRICH	1 - 4	1.8	0.14
TOLRPIND	0.04 - 0.21 *	0.08 *	0.24
DOM3PIND	0.56 - 0.81 *	0.12 *	0.24
TOTLRICH	31 - 56	8.7	0.38

* Values have been transformed with arcsin-sqrt.

Scale Biological Responses

$$m' = \frac{m - E[m_{ref}]}{STDEV[m_{ref}]}$$

m’ = 0 ➜ Conditions are the same as reference.

m’ = +/- 1 ➜ Conditions differ from reference by one standard deviation

Generalized Additive Models

Model responses as the sum of smooth functions:

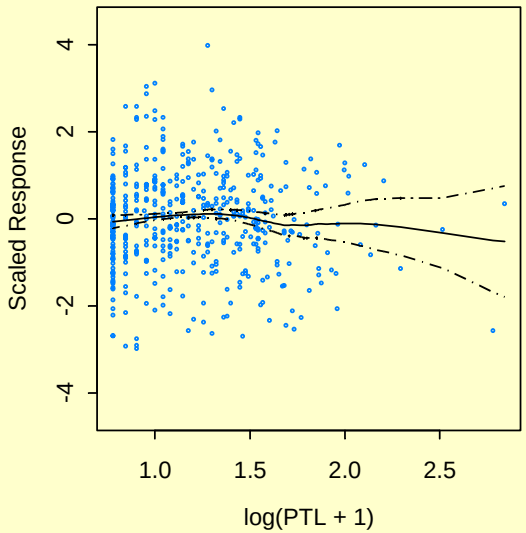
$$m' = b_0 + f(x_1) + f(x_2) + \ldots + f(x_n) + \varepsilon$$

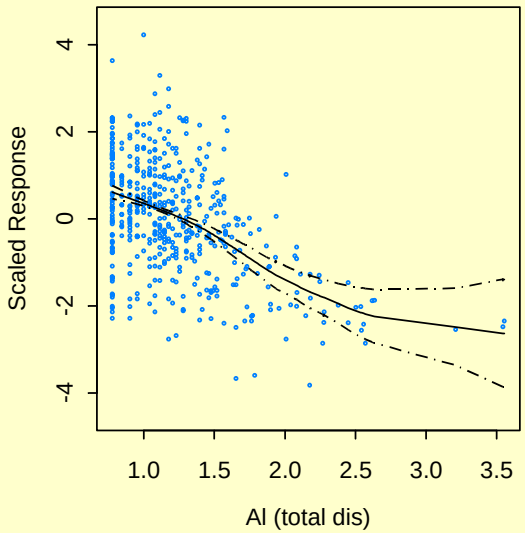
Compare to linear regression:

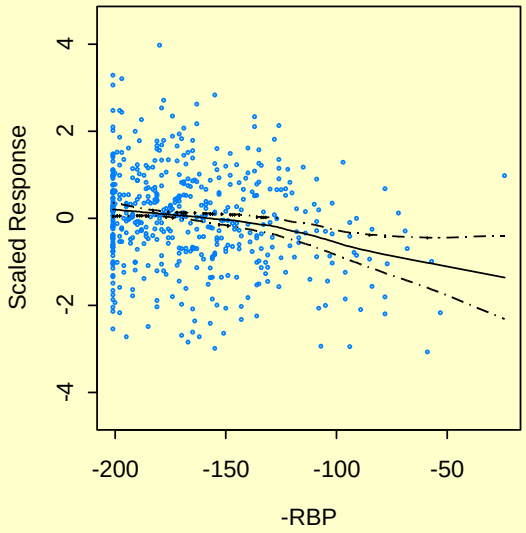
$$m' = b_0 + b_1x_1 + b_2x_2 + \ldots + b_nx_n + \varepsilon$$

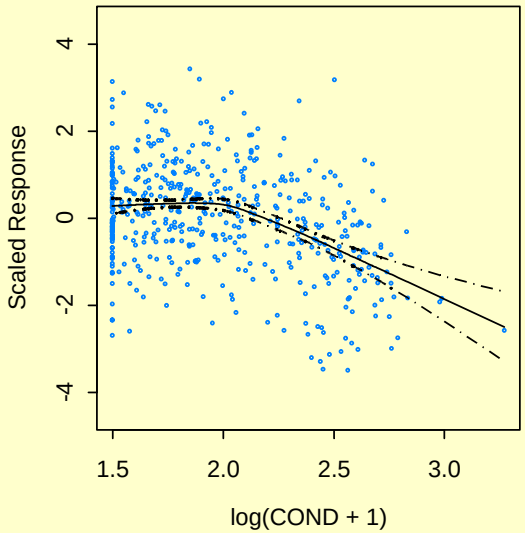
GAMs allow the representation of nonlinear responses.

Stressor-Response Relationships (Ephemeroptera Richness)

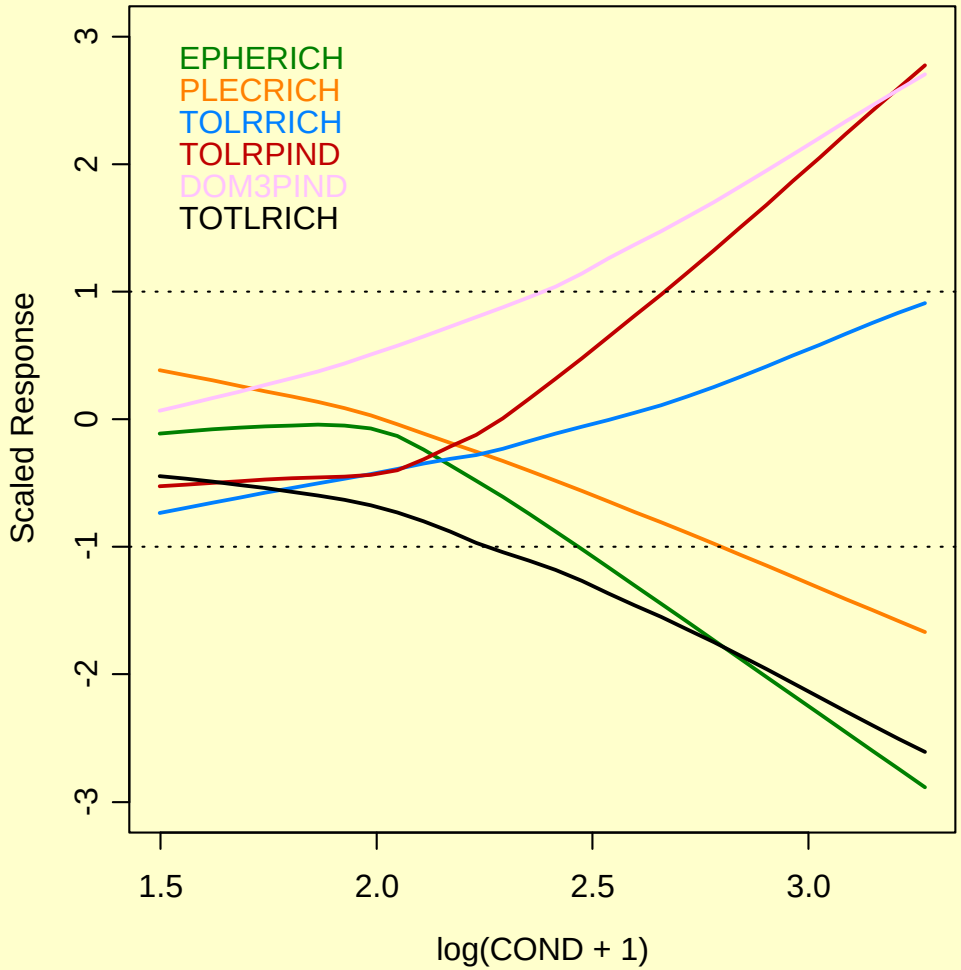




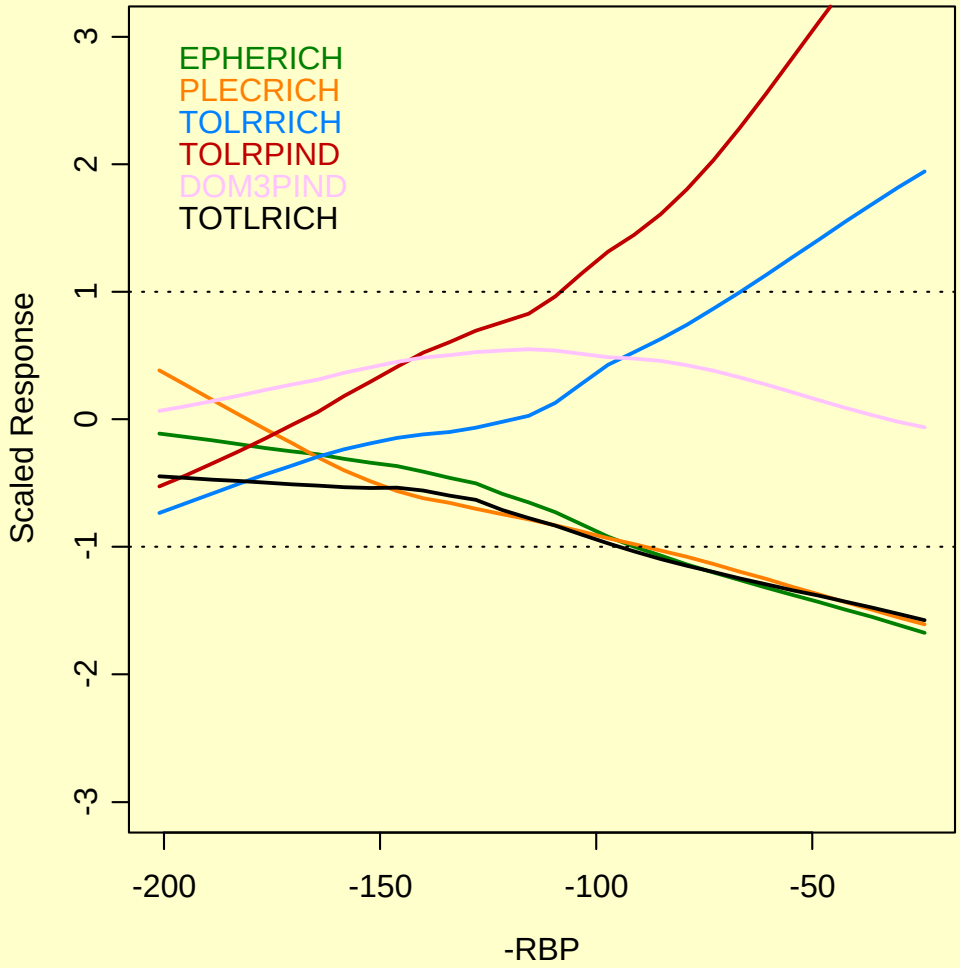




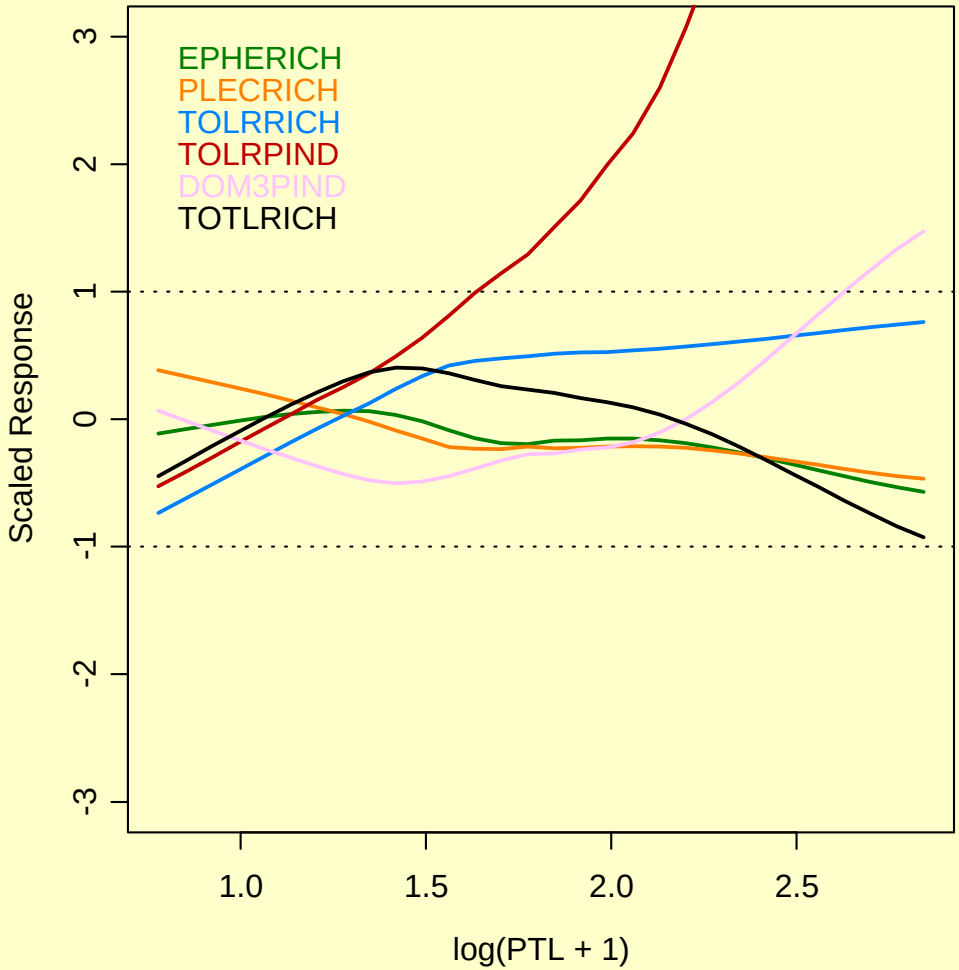
Responses to Ion Concentration



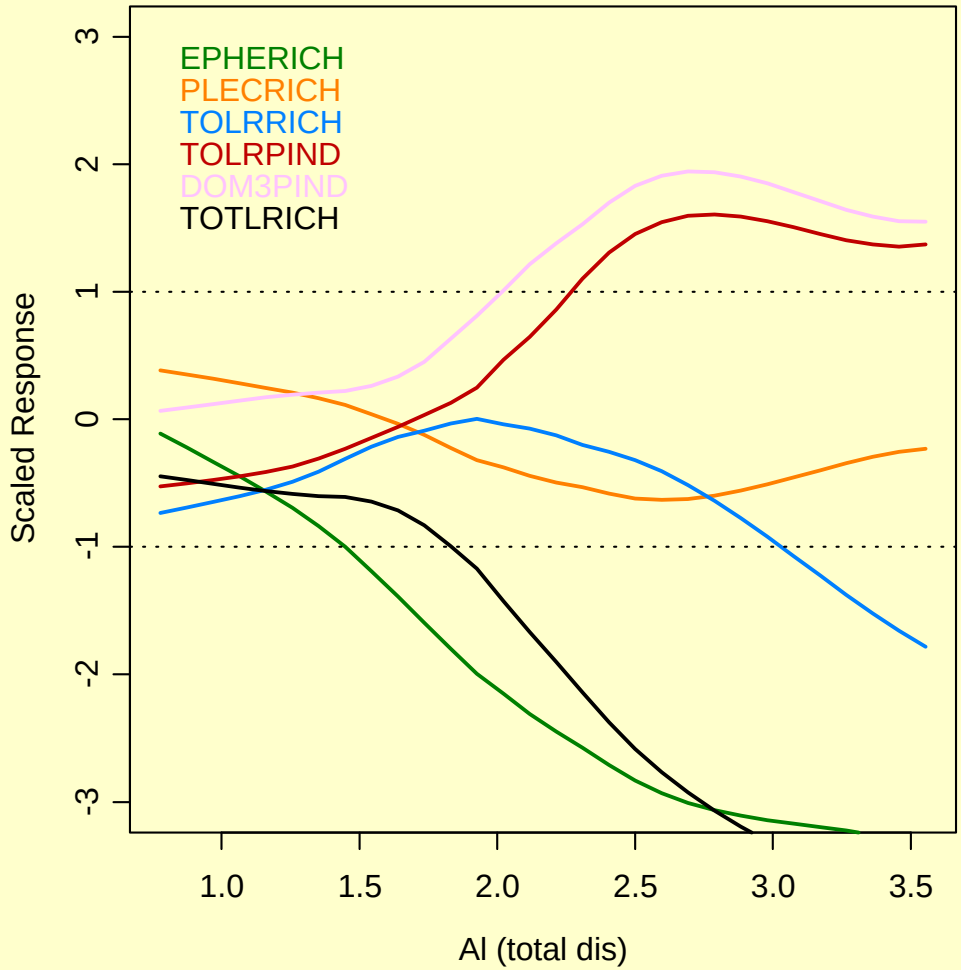
Responses to Habitat Degradation



Responses to Nutrient Enrichment



Responses to Metals



Conclusions

- Standardizing biological responses allows display of multiple metrics on one common set of axes.
- Relative sensitivities of biological metrics change with changes in stressors.
- Data display can lend support to establishing aquatic life use tiers.

Future Work

- Incorporate effects of anthropogenic factors on reference site observations.
- Analyze other covarying stressors.
- Combine with species-level analyses.
- Expand/refine definition of tolerant taxa.
- Expand to other study areas?

Acknowledgements

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